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RESPONSE OF BREEDING BIRDS TO AERIAL SPRAYS OF TRICHLORFON (DYLOX) AND CARBARYL (SEVIN-4-OIL) IN MONTANA FORESTS

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Contents

Response of Breeding Birds to Aerial Sprays of Trichlorfon (Dylox) and Carbaryl (Sevin-4-Oil) in Montana Forests[1]

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Abstract

Breeding density, food, nesting success, and mortality of 20 bird species were monitored at Beaverhead National Forest, Montana, in 1975 in conjunction with experimental applications of trichlorfon (Dylox) and carbaryl (Sevin-4-oil) to western budworms (*Choristoneura occidentalis*). Bird species on nine 350- to 550-ha forested plots (three controls and three treated with each pesticide) were studied before and for 14 days after the spraying of trichlorfon at 1.1 kg in 9.4 L of Panasol AN3 per ha (1 pound active ingredient in 1.0 gallon/acre) and of carbaryl at 1.1 kg in 4.7 L of diesel oil per ha (1 pound active ingredient in 0.5 gallon/acre).

No significant decrease in bird numbers was detected from breeding-pair estimates or live bird counts after the spraying. Of the breeding pairs present before spraying, 92% remained on control plots, 89% on trichlorfon plots, and 92% on carbaryl plots. Counts of live birds made before and after spraying in three types of habitat supported the results of the breeding-pair estimates. Nests with eggs or with young at the time of spraying were 74 and 97% successful, respectively, in control plots, 83 and 100% in plots sprayed with trichlorfon, and 86 and 100% in plots sprayed with carbaryl. No sick or dead birds were found after the spraying, although budworms were found in bird stomachs, and tracer-dye from the pesticide occurred on the feathers or feet of 74% of the 202 birds collected. Species dwelling in the tree canopy encountered the dye (and thus the pesticide) at a slightly higher rate (80%) than did species below the treetops (71%) or near the ground and in open areas (70%).

Larvae of the western budworm (*Choristoneura occidentalis*) defoliate conifers—primarily Douglas-fir (*Pseudotsuga menziesii*)—in the western United States where populations of the budworm are high (McKnight 1968). The U.S. Forest Service traditionally used DDT to control the budworm. For example, the Service applied DDT for western budworm control at the rate of 1.1 kg/ha (1 pound/acre) to 810,405 ha in Montana from 1952 to 1959, and at 0.6 kg/ha to 230,850 ha in 1960-1962, and 168,075 ha in 1963. In 1963, the last year in which DDT was routinely used, the Service tested two other insecticides, and since then has investigated various alternative chemicals in attempts to find an effective and environmentally acceptable method of controlling the western budworm.

Control agents must be evaluated by reliable methods for appraising their environmental effects (Leedy 1959). Once a candidate chemical shows potential to control a target pest, it is first tested in small-scale field experiments and eventually in a pilot control project of larger scale (to simulate operational conditions) before registration for operational control. The results of a pilot control project with trichlorfon (Dylox) and carbaryl (Sevin-4-oil), with particular reference to the effects of the chemicals on 20 bird species, are reported here.

Among insecticides used on U.S. forests, trichlorfon ranked first and carbaryl third by volume in 1973; carbaryl ranked first and trichlorfon second in 1974, if one excludes the emergency use of DDT in the Northwest (Fowler and Mahan 1975:50). Trichlorfon (0,0-dimethyl-1-hydroxy-2,2,2-trichloroethylphosphonate) is an organophosphate, systemic insecticide that is effective in the control of endoparasitic and ectoparasitic insects in livestock. It is toxic to many species of flies, wasps, bugs, and beetles (Matsumura 1975:74). Its lethal dietary concentration (LC_{50}) for young bobwhite quail (*Colinus virginianus*) on a 5-day con-

[1]This study was funded by the U.S. Forest Service and the U.S. Fish and Wildlife Service.

taminated diet is about 720 ppm (Hill et al. 1975). Carbaryl (1-naphthyl N-methylcarbamate) is one of the most widely used carbamate insecticides (Heath et al. 1972; Matsumura 1975:80). It has wide-spectrum effects on 100 to 150 species of insects, including the gypsy moth, *Porthetria dispar* (Matsumura 1975:80). The LC_{50} for carbaryl on young bobwhite quail exceeds 5,000 ppm (Hill et al. 1975). Both chemicals are known to inhibit brain cholinesterase (Zinkl et al. 1977).

The present report has two purposes: (1) to discuss the methods and procedures we used to evaluate the impact of these two chemicals on nontarget wild bird populations (published methodology for such studies is limited), and (2) to present our findings on the effects of trichlorfon and carbaryl on bird populations in a pilot study conducted in Montana in 1975. The U.S. Fish and Wildlife Service previously assessed the effects of trichlorfon and other chemical control candidates on bird populations during similar field experiments with forest insecticides (Pillmore et al. 1971*a*; Pillmore 1973). The present study was carried out in cooperation with the U.S. Forest Service.

Tests of field efficacy for control of western budworm require a relatively high population of the insect. Also, the test area, as recommended by the Forest Service, should be representative of the forest type and living communities that could be treated if such chemicals were approved for future use. The Beaverhead National Forest in southwestern Montana met all the requirements for the 1975 pilot project, including a western budworm outbreak in an advanced stage.

The highest kill of western budworm is effected when it is treated during fourth, fifth, and sixth instars (Flavell et al. 1978); these instars normally occur in late June in the study area. Additionally, this period coincides with increased food demands of forest birds during their breeding season. The adults and young of many forest bird species eat insects, either principally or exclusively, during the breeding period. During this time, the growing western budworm larvae may become an increasingly important food (Gage et al. 1970). A potential route for the contamination of insectivorous forest birds arises from their feeding on budworm larvae and other insects that become affected by the broad-spectrum sprays. Furthermore, a reduction in food supply during peak demands could retard growth or induce mortalities of nestlings, thus lowering productivity. Consequently, the time when entomologists believe the budworm is most susceptible to the insecticide is also a period of high vulnerability for birds.

In addition to following the two approaches recommended by Stickel (1973) for studies of organophosphates and carbamates—searches for sick or dead birds, and analyses of brain tissue or blood for cholinesterase inhibition—we determined the nesting success (the death of breeding birds or their departure from the area would result in lowered nesting success), censused live birds, and determined the food habits of resident birds. These techniques enabled us to monitor an important physiological variable, the population numbers, and the reproductive performance of the 20 most common species. This multi-faceted approach was used to reduce the chances of overlooking important effects of the spray applications on birds.

The common and scientific names of plants and animals mentioned in this report are given in the Appendix (Table A-1)

The Study Area

The test area lies in southwestern Montana within Madison County in the Tobacco Root Mountains and Gravelley Range. The nearly continuous mountain ranges extend from Butte south to West Yellowstone, Montana, and are bordered on the west by the Ruby and Jefferson rivers and on the east by the Madison River (Fig. 1). The central base for cooperative operations was established at Ennis, Montana.

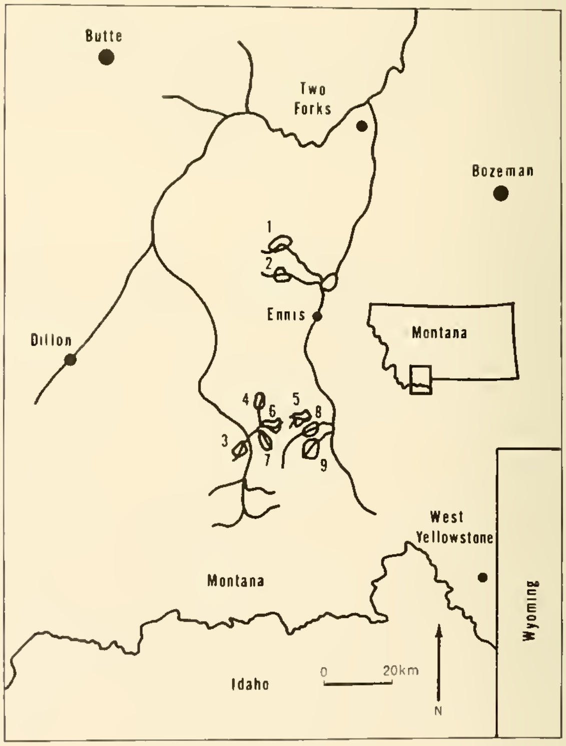

Fig. 1. Study areas showing drainages and placement of major study plots (1-9).

Nine 350- to 550-ha major plots were established at 1,890- to 2,380-m elevation in drainages on the east and west slopes of the two mountain ranges (see Table A-2 for plot descriptions). Hereafter, the term major plot (MP) is applied to one of these large areas (sprayed or unsprayed), and the term subplot (SP) is applied to an 8.1-ha area established within each major plot that was used for studies of breeding pairs. Fixed stations (FS) refer to localities inside the MP's, but separate from the SP's, where birds were counted while the observer stood still.

Spring weather in 1975 was unusually cool; rain fell in the lower valleys and snowfall continued in our study area through mid-June. Plant development was apparently 2 to 4 weeks later than in most other years. However, deciduous woody species were fully leafed by about 1 July, 10 days before treatment began. The early-season cool weather may have delayed entry of migrant birds into the study area. After the weather changed to a more typical spring and summer pattern, near mid-June, several species—including western tanagers which had still been congregated at lower elevations—moved into higher elevation breeding areas. By late June most species of breeding birds were nesting. Near-normal summer weather continued through June and July, except for frequent afternoon showers and cool nights that slowed the growth of buds of coniferous trees. As a result, the western budworm, whose growth depends on bud developments in Douglas-fir, did not reach "treatable" instar stages until 10 July. Spraying began on that date.

The Flora

Vegetation in the study area is a mosaic of forested and nonforested habitats (Fig. 2), dominated by timbered types with considerable nonforested clearings. Vegetation in the clearings included sagebrush, grasses, and forbs (collectively called grassland, Pfister et al. 1977). Timber on the five MP's on the east side of the Gravelley Range (1, 2, 5, 8, and 9) were logged sporadically 30 years or more ago (Virgil Lindsay, personal communication), but were well established forests during our study. Among the four remaining MP's (3, 4, 6, and 7) on the west side of the range, some timber in parts of MP 4 was cut during 1959-62; the other plots had no history of recent cutting (John R. Hook, personal communication).

A program of controlling sagebrush with herbicides in MP's 1, 2, and 4 during 1968-70 killed some of the sagebrush, but irregular, apparently untreated patches were present during our study. The other six MP's (3 and 5-9) had no history of sagebrush control (John R. Hook and Virgil Lindsay, personal communication). Some MP's supported nearly dead but regenerating stands of sagebrush, whereas sagebrush in other plots appeared healthy, or partly decadent and partly healthy. We established the FS's in dead, regenerating, or vigorously growing sagebrush stands, without considering their condition as a criterion for selection of the stations.

Fig. 2. A mountainous area where major plots were located, showing the pattern of vegetation distribution. The forest has a considerable number of openings, typical of plots 3, 4, 6, 7, and 9. Plot 7 is in the immediate foreground.

Douglas-fir occurred in continuous stands on slopes facing north and east but was sparse on other slopes. It was the dominant tree species, although it intergraded with lodgepole pine, which replaced the Douglas-fir at the upper elevations (Fig. 3). An occasional limber pine was found on rocky, xeric slopes with southern exposures at lower elevations. No ponderosa pine occurred in the study area. Species of true firs and spruce were generally less common, growing mostly in mesic sites restricted to stream bottomlands and spring-fed areas. Woody riparian habitat was limited to a narrow belt of willow and birch along the small permanent streams that ran through all MP's except No. 5.

Quaking aspen (Fig. 4) was common in all MP's except No. 8. Aspen was usually in small homogeneous groves; extensive stands were found only in MP 7. Aspen was most prevalent at the interface of the upper elevation limits of grassland and sagebrush areas, where coniferous stands begin, as well as along streams and in wet areas (Fig. 2). Wet areas were characteristically in the stream bottoms and along the lowest elevation of the MP's. An extensive description of the dominant Douglas-fir and lodgepole pine climax series in this area, including the understory associations with these forest types, was given by Pfister et al. (1977).

Because sagebrush-covered openings occurred on all MP's, and were considered important, we located SP's

Fig. 3. A slope of South Meadow Creek with a northern exposure, showing dense Douglas-fir forest (foreground) blending into a lodgepole pine forest (background). This combination is more typical of subplots (SP's) 1, 2, 5, and 8 than of the others. Subplot No. 2 for breeding-pair surveys included the sagebrush, aspen, and Douglas-fir habitats in the foreground.

Fig. 4. Interior of the subplot (SP) on major plot (MP) 2, showing typical habitats of Douglas-fir on the north slope (left and background) and aspen and sagebrush on the south slope (right and foreground).

and FS's in this habitat; it closely resembled the big sagebrush-Idaho fescue series described by Mueggler and Handl (1974:32). Major plot 5 was slightly atypical in that it had only small sagebrush areas available for bird counts.

Habitat for bird studies was similar in all MP's, although the relative proportions of nonforest types varied among plots. We recognized three broad habitat types for stratification of the FS bird census, although we realized that our habitat characterization was somewhat artificial. The three habitat types were delineated by their characteristic overstories: (1) Douglas-fir—all conifer stands, (2) aspen—mostly pure aspen, and (3) sagebrush. These habitat types were common to all MP's, which had varying understories of grasses, forbs, and some shrubs. The three habitats of SP 2 shown in Fig. 4 are representative of the habitats in the other SP's. A more extensive description of each treated MP was given by Flavell et al. (1978).

The Fauna

The Beaverhead National Forest is well known for its populations of big game and upland game (Mussehl and Howell 1971) and its fisheries (Brown 1971). And, as in most forest ecosystems, abundant insects support a rich diversity of birds. The abundance of some insectivorous bird species, and perhaps their predators as well, may have been increased as a result of the high population of western budworms.

Elk, moose, and mule deer were abundant on their winter range in the lower valleys and foothills and dispersed in early May through the MP's and upward into their summer range as the snow cover receded. Cattle that were herded into the MP's near the beginning of the postspray counts rapidly reduced much of the dense grass and forb understory. These wild and domestic animals trampled some ground nests that we monitored.

We primarily studied birds nesting during June and July, but considered other species as well. Most were migratory. Of the 31 most abundant species (2 Falconiformes, 2 Piciformes, 27 Passeriformes) 4 normally arrived in March, 7 in April, and 17 in May (Skaar 1969). The other three species were residents, but their numbers increased during the breeding season. We were unable to assess the effects of the spray program on the only game birds present—blue grouse, ruffed

grouse, and mourning dove—because they were either too scarce or nested too early.

Peak egg laying and incubation of most species was in late June (Fig. 5). The fledging of young began in late June, peaked in July at about the time the MP's were treated, and ended by early August. Nesting of most passerine species begins in May and lasts about 2½ months, being restricted to a short period when food is abundant at this latitude and altitude. However, the dark-eyed junco, which winters in the area, and the American robin, which arrives early, both commonly nest twice per season. This was evidenced by robins on eggs in their first nests by late May (even during snowstorms), and juncos that built their second nests in middle to late July.

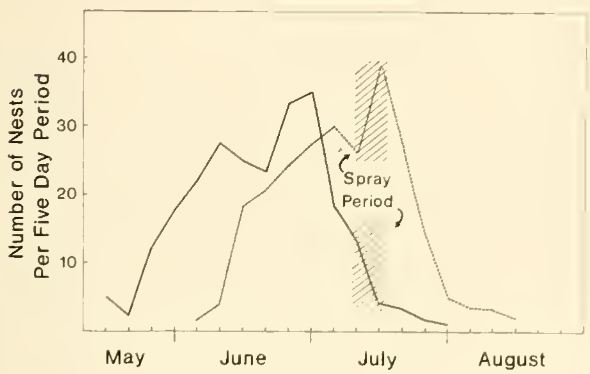

Fig. 5. The phenology of nesting of 27 forest breeding species studied. The solid line represents frequency of nest initiations (1 day before first egg laid) and the dotted line the frequency of hatching. All of the 247 nests that were started are included, regardless of whether they were successful. Vertical lines indicate the 10-17 July period when the six major plots of the study area were sprayed. Each tick on the X axis represents 5 days.

Methods

The experimental design was completely randomized with three treatments (trichlorfon, carbaryl, and control) and three replicates. Three of the nine MP's were sprayed aerially, through 18-8010 Tee Jet nozzles, with carbaryl diluted in diesel oil 1:1 at the rate of 1.1 kg in 4.7 L/ha (1 pound active ingredient in 0.5 gallon/acre) and three were sprayed through 37-8010 Tee Jet nozzles, with trichlorfon diluted in Panasol AN3 oil 1:3 at the rate of 1.1 kg in 9.4 L/ha (1 pound active ingredient in 1.0 gallon/acre). No adhesive sticker was used in the formulations. An automate-red dye that persisted for several days was mixed into both formulations by the U.S. Forest Service for the assessment of spray coverages. Three MP's—the controls—were not treated.

The spray was applied from a Bell 205 A-1 helicopter fitted with a pump capable of maintaining 2.8 kg/cm² pressure in the spray boom during spraying. The 15.2-m spray boom fitted on the helicopter yielded an effective swath width of 61 m.

Spraying began at dawn and was completed by 1000 h; only one MP per day was sprayed. Spraying of plots extended from 10 to 17 July (Table A-3); rain prevented spraying on 2 of the 8 days. All plots were sprayed when winds above the forest canopy were less than 10 km/h (Scuderi et al. 1975), and the spray appeared to fall into the forest with little noticeable drift. A broken spray-boom hose caused a spill of trichlorfon over MP 5. However, the spill was corrected after one swath of undetermined length. Although some of the spilled chemical may have fallen on parts of the SP's and FS's on MP 5, most of the excess spray apparently fell 400 to 600 m away. We are uncertain whether the spill had any unusual effects on birds in our study areas in MP 5.

During May and June we established a rectangular 8.1-ha (402 x 201 m) SP in each of the nine MP's, using a staff compass and surveyor's tape. Counts of birds on these SP's provided estimates of the density of breeding pairs (Fig. 6). Inasmuch as breeding bird density and species richness decrease progressively from heterogeneous mixtures of deciduous and conifer types along moist creek bottoms, up the slopes into dryer homogeneous conifer stands (Balda 1975), we established each SP along the principal stream course to insure the highest possible breeding bird density and number of species. The principal stream occurred near the edge of some MP's (4, 6, and 7) rather than through the middle as in MP's 1-3, 5, 8, and 9 (Fig. 6). Douglas-fir, aspen, and sagebrush habitats occurred in each SP.

In each SP we established 66 points, each marked by an orange-painted wooden stake (122 cm high), along a grid at 40.2-m intervals (Pillmore 1973:145). This grid was duplicated on field forms for the recording of bird observations at precise locations within each SP.

In addition to having one 8.1-ha SP within each of the 9 MP's, we established a separate series of 9 to 15 roughly circular or oval FS's in each MP (Fig. 6). The FS trend counts made at these plots were similar to those made by Fowler and McGinnes (1973). These FS's were stratified by dividing them among Douglas-fir, aspen, and sagebrush habitats (Table A-4) to reduce the variance contributed by unequal bird densities in different habitats. We monitored all three habitat types because we expected different habitats to support unlike species and unequal densities of birds (Kendeigh 1944:100). One to five FS's were marked with surveyor's flagging at their central point and

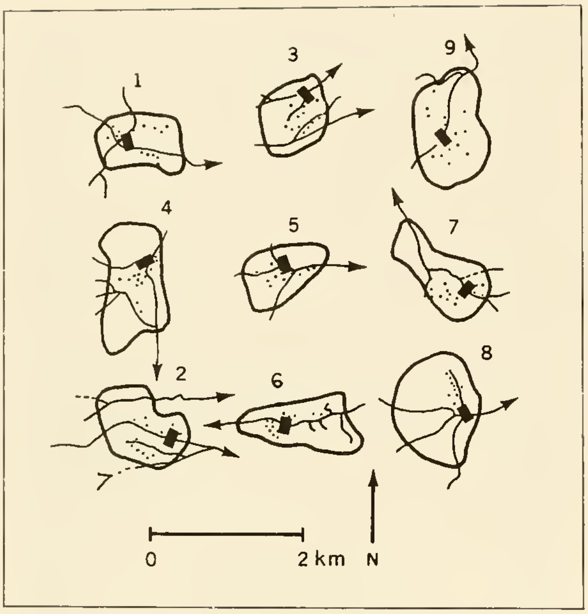

Fig. 6. Nine major study plots (MP; see Fig. 1 for locations), showing relative size, shape, relation to drainage, direction of drainage; and 8.1-ha subplots (SP; solid rectangle); and fixed-station plots (FS; dots). Plots 1, 3, and 9 were controls; 4, 5, and 7 were treated with trichlorfon; and 2, 6, and 8 were treated with carbaryl.

periphery in each of the three identified major habitats in each MP. Adjacent FS's were all more than 91 m apart, thus providing nearly independent counts at each FS. The numbers of FS's varied from 9 to 15 per MP and the average areas from 0.09 to 0.74 ha, depending on the visibility through, and availability of, habitats (Table A-4). The dimensions of each FS were paced, and the area was calculated. Because counts at FS's were scattered throughout the MP's (except for MP 8), birds counted at FS's generally were farther inside the MP's (i.e., nearer the center of the sprayed areas) than were those in the SP's (Fig. 6).

Bird Census Techniques

Breeding-pair Estimates

Two types of systematic living-bird censuses were made in the MP's during the prespray and postspray periods. The first was a 2-h breeding-pair count on each 8.1-ha SP, which began at sunrise (0540-0610) on each count day (see Table A-3 for count days). An observer walked a standardized route, counting all birds either seen (stationary or flying) or heard (territorial or nonterritorial), and plotted them on the 66-point grid form for the SP. Weather data, bird behavior, nest locations, and the presence of sick or dead birds were also recorded. We used the breeding-pair mapping method (Williams 1936) for an estimate of breeding pair density (see also Hall 1964 and Svensson 1970).

Subjective biases inherent in the breeding-pair mapping technique (Best 1975) were considered: each observer plotted species maps for his or her three SP's, but one person interpreted all of the species maps and determined the numbers and locations of breeding pairs.

We recognized that this technique, at best, may reveal only about one-fourth of an actual population reduction (Robbins 1963), and that rapid repopulation may mask any actual reduction (Stewart and Aldrich 1951). Because of this shortcoming, we also employed the FS census as a second method.

Fixed-station Census

The second census was a count of birds from the center of each of the total of 114 marked FS's (Fig. 1), which provided a separate estimate of bird abundance and species composition. Counts at the stations began 2 h after sunrise (0740-0810) and took 2 to 3 h to complete. Stations were occupied by the counters in the same order on each count day. Upon arrival at the center of each station, the observer stood motionless for 1 min to allow for the resumption of bird activity, and then recorded individuals of all species from this central point for 5 min. The locations where birds were seen were plotted on duplicated sketch maps of the FS plots. A bird that moved about during the count was tallied as one bird.

Preliminary trials indicated that often no birds were tallied inside the flag-marked FS's. These zero counts were attributed to a number of factors: the shyness of birds; the inevitable smallness of FS's caused by the sparseness of some habitats (aspen and sagebrush) within the limits of the MP boundary; obstruction to bird observation imposed by large trees (Douglas-fir and aspen); and the necessity to have areas set aside within MP's for the collection of live birds by other researchers for cholinesterase studies. Consequently, to counter the low numbers of birds tallied inside, we combined the birds inside FS's with those seen or heard outside the FS's and categorized our observations into two primary groups: (1) birds registered only inside the boundary of each FS, and (2) total birds—the sum of birds inside and outside the boundary.

Both primary groups included birds either seen (stationary) or heard (territorial or nonterritorial). Only birds perched either within the flagged FS boundary or in the outside area were counted. The maximum distance from the center point to the point at which birds were recorded did not exceed about 75 m (station radii

were 10 to 60 m). This distance was arbitrary, and varied because of differences in habitat and topography. However, two rules governed this type of count. First, the same bird detected at the same location from two adjacent stations was recorded at only one station. Independency of counts at all stations was required for the statistical analysis; counts at each station were to represent different birds. And, second, once the counts began, the observers made maps and plotted landmarks marking the outer boundaries of the "outside area" for each station, and restricted counts to this same outside area throughout the study.

Data from this census were treated as three interrelated numerical values from each of the three designated habitat types: (1) a crude estimate of number of birds per hectare from birds inside the station boundary, (2) an estimate of numbers of singing males from inside and outside the station boundary combined, and (3) an estimate of total bird numbers, in which all birds (males and females) inside and outside the station periphery were combined. These three estimates were used in prespray and postspray comparisons. Estimates (2) and (3) included birds in the designated habitat, inside the fixed stations, and also from adjacent habitats, which sometimes differed from that of the stations; thus, unlike estimate (1), they included birds from more than one kind of habitat.

Statistical Techniques

The methods for analyzing many of the data presented in this report are discussed in later subsections. Fixed-station bird counts presented a particular problem common to studies in which animal numbers are counted repeatedly in the same place over a period of time. Two sources of variation involved in comparing prespray with postspray bird counts confounded the detection of treatment effects: an elapse of time and pesticide treatment. We removed the time factor from our FS data by analyzing 27 values (3 treatments x 3 habitats x 3 replicates), derived by subtracting the postspray mean from all stations in a given habitat, and in a given plot, from the corresponding prespray mean. We then used a split-plot 3 x 3 factorial analysis of variance (Steel and Torrie 1960:236) to analyze the data.

Three observers were each assigned three MP's, each with a different treatment (control, trichlorfon, and carbaryl); only one observer worked in any given MP during the study. Bird censuses were conducted during the morning and nest studies and carcass searches during the afternoon. One plot that received each treatment was surveyed on each count day from mid-June through July (Table A-3). This procedure tended to reduce the effects of weather, observer, and plots when plots of like treatment were combined for comparison. We scheduled postspray counts so that all plots were censused nearly the same number of times on days representing about equal posttreatment intervals. All postspray counts began on the 1st day after treatment and were repeated at intervals 2-4, 6-7, 9-11, and 13-14 days after treatment. Censuses on control plots were divided into prespray and postspray periods similar to those on the sprayed plots. Five censuses were made on all SP's and FS's in the 2½-week period before and after the insecticide application.

Nesting Studies

To supplement the census data, we recorded bird nests seen in each of the MP's. All nests located were monitored to determine fledging success. Nests in cavities were observed with cavity viewing devices described by De Weese et al. (1975) and Seidensticker and Kilham (1969).

Nesting success information was gathered only from nests that were active (i.e., that contained either eggs or young) on the date of spraying. No attempt was made to evaluate the few nests that were initiated after the spraying dates.

Casualty Searches

We searched for "sick" birds showing toxic signs, and dead birds, during the prespray and postspray periods. Hours expended on this effort were recorded for each plot. Birds found sick or dead were also noted during the early-morning censuses.

Stomach Contents Analysis

Stomachs of 183 birds of eight species that were collected for a cholinesterase study were retained for food content analysis. Birds were collected alive with shotguns during the morning at points adjacent to the MP's before treatment, and in the MP's after spraying. Birds were not collected in treated MP's any closer than 90 m to an SP or FS and never on census days. Birds were kept on dry ice or in a freezer until the stomach contents were removed.

Food items washed from the esophagus, proventriculus, and ventriculus of each bird were analyzed collectively as stomach contents. Plant, animal, and grit materials were sorted and visual estimates of the percentages by volume were made as described by Crase (1977). The percentage of the total number of insect food items was measured by counting individual

insects (Martin et al. 1951). It was sometimes necessary to determine the number of insects by counting body parts (e.g., the total parts that come from different insects equalled the minimum number of insects represented by those parts). Where actual counts were not possible because of advanced digestion, insect numbers were estimated. Most insects were identified to order, and the western budworm to species.

Occurrence of Spray on Birds

Birds collected for cholinesterase studies for the 5 days during and after the spraying were examined for automate-red dye. Comparisons among the bird species for exposure to the dye was made on the basis of the forest canopy level that they usually inhabit.

Results and Discussion

Breeding-pair Estimates

Sixty-six bird species were observed on at least one of the 8.1-ha SP's and 34 species were found breeding on nearly all SP's. Of the breeding species, 20 (1 consisting of 3 species of flycatchers combined) exhibited territorial or breeding behavior and were numerous enough to support comparisons between treated and control plots (Table 1). Evening grosbeaks and pine siskins were abundant on all plots, but their erratic and wide-ranging movements precluded a usable estimate of breeding density. The postspray estimate of breeding pairs for the 20 selected species were 92% of the prespray estimate in the control plots, 89% in the trichlorfon plots, and 92% in the carbaryl plots. Postspray estimates were consistently lower than the prespray estimates, but these decreases occurred on treated as well as untreated plots and were not significant ($P = 0.50$; Steel and Torrie 1960:101).

The 20 species were also categorized by their spatial feeding habits (Thomas et al. 1975; Bent 1939, 1942, 1946, 1948, 1949; Martin et al. 1951; present study, Table 2 and Table A-1). Simple broad feeding categories were used, so that we could easily classify a species and yet maintain enough ecological difference between it and others for comparison. In this approach we assumed that the farther below the treetop level a species foraged and the greater the distance and amount of foliage between the spraying device in the helicopter and a species' activity area, the less the species would be exposed to the spray.

Changes in postspray breeding-pair estimates, when grouped by feeding habits, were observed in control and sprayed SP's (Table 2). In categories containing more than 20 pairs before the treatment, the total numbers of breeding pairs of aerial feeders decreased 27% in control plots and 24% in the trichlorfon plots (Table 2). The only other categories that indicated noteworthy postspray changes were tree-canopy feeders on all SP's (12 to 18% decrease) and understory feeders on control SP's (43% increase). Postspray changes in other categories were either minor or the samples were too small for meaningful analysis.

Changes in total breeding-pair estimates after spraying were slight, but some species seemed to decrease more than others. A decrease in density of a particular species could be more severe than for other species. Prespray and postspray breeding-pair estimates for the 12 most abundant species are presented in Fig. 7. The eight other species included in the breeding-pair count were not abundant enough for comparison. The *Empidonax* group accounted for 100% of the postspray drop of the two aerial feeders (*Empidonax* spp. and tree swallow) in control and trichlorfon plots; tree swallows decreased only in carbaryl plots. The yellow-rumped warbler, warbling vireo, and western tanager accounted for about 90% of the decrease of tree-canopy feeders in trichlorfon plots. The disappearance of mountain bluebirds after carbaryl treatment and of white-crowned sparrows and Cassin's finches on control plots after the spraying was noticeable, but densities of these birds were too low to suggest meaningful comparisons. The increase of lazuli buntings after treatment probably reflected their late arrival on the study area. Postspray censuses indicated that no species that was abundant before spraying was decimated by either of the treatments.

For three species (chipping sparrow, yellow-rumped warbler, and house wren) the estimated number of breeding pairs after treatment was reduced in treated plots, but not in control plots. When averaged over replication, estimated numbers of postspray breeding pairs of these three species were lowered by 14, 40, and 14% in trichlorfon plots and 6, 8, and 28% in carbaryl plots, compared with no decrease in control plots (Table 1).

Pooled postspray estimates of the numbers of yellow-rumped warblers decreased more in trichlorfon plots than did any of the other 12 selected species in all other plots. Further, SP 5 accounted for 50% of the yellow-rumped warbler pairs that were missing after spraying in the trichlorfon treated plots. The treatment of MP 5 possibly had a greater impact and also a greater general effect on birds than that of any other treated plot. Not only did the observer note a general decrease of bird activity there after treatment, but breeding-pair numbers dropped 29%, compared with 0-12% in all other plots (Table 1). However, the spray treatment of MP 5 differed from all other plots: treatment was made on 2 consecutive days, and, as mentioned earlier, a spillage from the aircraft occurred

Table 1. *Estimated pairs of breeding birds of the 20 most common species on the nine 8.1-ha treated and untreated subplots, based on five prespray and five postspray counts.*[a]

		Control						Trichlorfon						Carbaryl					
	Prespray rank of	Prespray			Postspray			Prespray			Postspray			Prespray			Postspray		
Species	abundance	1	3	9	1	3	9	4	5	7	4	5	7	2	6	8	2	6	8
Common flicker	19	0	1	1	0	1	1	1	1+	1	1	0	2	P	1+	P	P	2	0
Yellow-bellied sapsucker	16	2	P	1	2	1	1	1	1	1	0	0	1	1	0	1	1	1+	0
Empidonax spp.	2	7	5	6	4	4	4	7	4	3	4	3	2	7	6	5	9	4	6
Tree swallow	12	2	1	1	2	1	1	2	1+	4	2	0	5	1	3	P	0	2	0
Mountain chickadee	7	2	4	4	2	4	3	4	3	3	3	2	4	3	4	5	2	4	2
House wren	10	2	2	2	3	2	3	3	2	2	3	1+	2	3	4	0	2	3	0
American robin	4	8	3	3	5	3	6	6	2	3	8	1+	4	6	8	3	4	6	5
Hermit thrush	16	0	2	1	0	1	0	P	1	0	0	1	P	1	0	3	1	1	3
Swainson's thrush	13	4	1	1	3	0	1	1	0	1	1	0	1	2	0	3	2	0	3
Mountain bluebird	20	1	0	0	1	P	0	1	P	1	0	0	1	0	1+	0	0	0	0
Ruby-crowned kinglet	8	1	4	4	0	2	3	3	2	P	2	3	P	3	4	3	3	2	2
Warbling vireo	1	7	3	7	4	3	6	8	5	6	9	4	3	9	6	4	10	6	3
Yellow-rumped warbler	6	4	4	5	4	4	5	6	3	1	5	1+	P	5	3	4	5	3	3
MacGillivray's warbler	13	0	0	2	1	1	2	2	2	2	3	2	0	2	0	3	1	0	4
Western tanager	9	1	3	3	2	3	3	2	2	0	0	2	0	5	2	3	5	3	3
Lazuli bunting	11	3	0	1	5	0	3	1	2	0	3	3	0	4	2	2	4	2	3
Cassin's finch	18	P	P	1	0	0	0	2	P	P	1	0	2	2	2	0	1	2	0
Dark-eyed junco	5	4	4	4	4	6	2	6	2	5	6	2	5	3	6	3	3	6	2
Chipping sparrow	3	3	6	5	4	6	4	6	5	3	4	4	4	5	6	5	5	6	4
White-crowned sparrow	15	1	1	0	0	P	0	2	0	3	3	0	3	2	0	0	2	P	0
Plot total		52	44	52	46	42	48	64	38	39	58	29	39	64	58	47	60	53	43
Grand total			148			136			141			126			169			156	

[a]P = species that occurred on a plot in insufficient numbers for pair determination; 0 = species that did not occur on a plot; + = at least one observation suggested an additional pair, but the evidence was insufficient to allow inclusion among full breeding pairs; of 180 possible instances of occurrence (9 plots × 20 species), 10 species (none of which ranked higher than 8th) were absent from one to three plots in 16 instances.

[b]Probably includes *Empidonax traillii* (willow flycatcher), *E. hammondii* (Hammond's flycatcher), and *E. oberholseri* (dusky flycatcher); the dusky flycatcher was probably the most common.

Table 2. *Estimated numbers of breeding pairs of 20 selected species, grouped by spatial feeding habits, in subplots (SP's) with differing treatments, and (in parentheses) percentage change after treatment.*

		Treatment					
Spatial feeding	Number of	Control		Trichlorfon		Carbaryl	
habit[a]	species	Prespray	Postspray	Prespray	Postspray	Prespray	Postspray
Aerial	2	22	16 (-27)	21	16 (-24)	22	21 (-4)
Tree canopy	6	57	48 (-16)	50	41 (-18)	67	59 (-12)
Tree trunk	1	3	4 (+33)	3	1 (-67)	2	2 (0)
Understory	4	14	20 (+43)	21	23 (+10)	22	21 (-4)
Ground	6	51	47 (-8)	44	44 (0)	55	53 (-4)
Air-Ground	1	1	1 (0)	2	1 (-50)	1	0 (-100)
Total	20	148	136 (-8)	141	126 (-11)	169	156 (-8)

[a]Species in relation to the spatial feeding habits designated here are given in Table A-1.

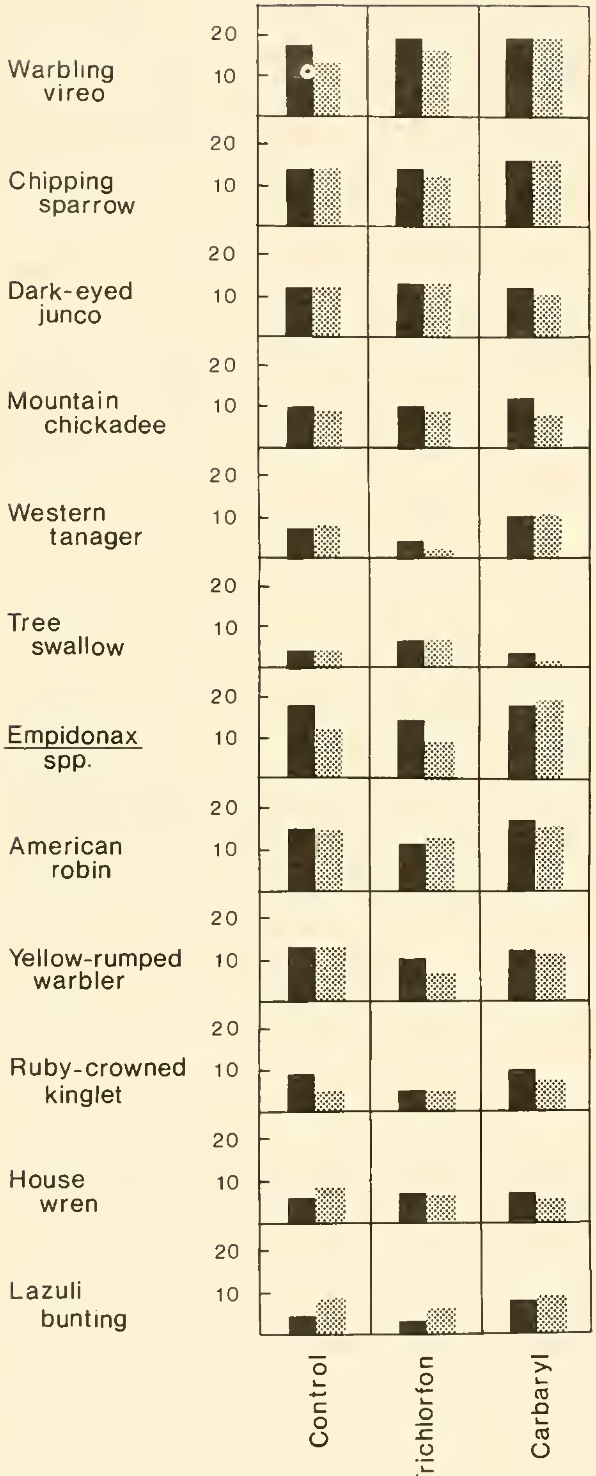

Fig. 7. Estimated numbers of breeding pairs of the most abundant species found in the trichlorfon and carbaryl treated plots and controls (three plots for each treatment) before spraying (solid bar) and after spraying (stippled bar).

during treatment.

Other investigators of the effects of trichlorfon and carbaryl on wild bird populations have used various techniques, sizes of treated areas, chemical formulations, rates of application, and a variety of vegetative types (Table A-5).

Only one of the studies have shown measureable effects of treatment: Moulding (1976) reported that mean numbers of forest birds, based on transect counts, declined significantly by 2 weeks, and were depressed for as long as 4 to 6 weeks after the forest was sprayed with carbaryl (1.1 kg active ingredient per ha in water with pinolene sticker). Canopy-feeding birds tended to be more affected than ground-feeding species. The bird populations had not recovered 8 weeks after spraying, presumably because of a reduction in the food supply in the forest canopy.

Our breeding-bird data suggest that canopy-feeding birds were not significantly sensitive to either insecticide, but that they were more sensitive to trichlorfon than to carbaryl.

Other studies have not shown significant effects on forest birds: although data shown by Pillmore et al. (1971*b*) suggested a decline in breeding pairs of the yellow-rumped warbler and ruby-crowned kinglet (both canopy dwellers) in a forest area sprayed with trichlorfon, his results in general were inconclusive because the area had been treated with synthetic pyrethrum (2.2 kg active ingredient per ha) in the preceding year. Also, breeding pairs of both species decreased after the spraying by 67 and 28% in two plots treated with trichlorfon but likewise decreased 28% in one control plot.

Doane and Schaefer (1971) reported a reduction in the numbers of 13 bird species heard singing on 20-ha plots in an urban forest in Connecticut treated with trichlorfon or carbaryl (1.1 kg active ingredient per ha). They concluded that a 99% kill of gypsy moth larvae forced birds to forage outside the sprayed plots, thereby affecting the singing rate or the numbers of singing males inside the plots, or both. One consideration that is overlooked is the possible response of territorial males when food in existing territories is drastically reduced. We believe that lower food supplies within a bird's normal foraging range may have far-reaching effects on singing activity, intraspecific strife, and overall productivity. There is evidence, at least for mammals (Boyd and Taylor 1969), that a lowered dietary intake of protein increases susceptibility to some insecticides.

Conner (1960) found no effects of carbaryl (1.4 kg active ingredient per ha) on numbers of common songbirds and singing locations of male songbirds in a New York mixed forest after treatment. No adverse effects on birds were observed by Richmond et al. (1979) when carbaryl (2.2 kg active ingredient per ha) was applied in forests of northeastern Oregon—although 2 of 55

Table 3. *Means (±95% confidence intervals in parentheses) of 5-min bird counts made at fixed stations (FS's) before and after the treatment.*

Habitat type and treatment	Number of counts[a]	Area[b] (ha)	Prespray: Within fixed station boundary[c]	Prespray: Total birds[d]	Prespray: Territorial males[e]	Postspray: Within fixed station boundary[c]	Postspray: Total birds[d]	Postspray: Territorial males[e]
Douglas-fir								
Control	70	5.5	5.6 (1.3)	9.8 (0.7)	5.1 (0.7)	7.0 (1.7)	11.1 (0.8)	6.4 (0.5)
Trichlorfon	75	6.3	4.2 (1.0)	8.0 (0.7)	3.6 (0.5)	2.9 (0.8)	8.0 (0.8)	4.2 (0.6)
Carbaryl	65	5.5	4.1 (1.0)	10.2 (0.8)	5.4 (0.8)	4.0 (0.8)	10.9 (1.0)	6.0 (0.6)
Aspen								
Control	70	3.8	15.3 (4.2)	8.6 (0.8)	4.0 (0.5)	10.2 (3.1)	8.7 (1.0)	4.7 (0.5)
Trichlorfon	65	3.6	21.9 (5.8)	10.3 (1.0)	4.5 (0.6)	15.1 (4.5)	10.2 (1.0)	5.2 (0.6)
Carbaryl	45	3.2	11.4 (2.3)	10.2 (1.2)	4.9 (0.7)	7.8 (1.5)	10.2 (1.0)	5.4 (0.7)
Sagebrush								
Control	65	6.7	3.6 (1.0)	10.4 (1.0)	5.5 (0.6)	2.1 (0.7)	12.1 (0.8)	7.3 (0.6)
Trichlorfon	55	7.0	2.1 (0.7)	10.9 (1.0)	6.1 (0.8)	1.6 (0.8)	10.3 (0.9)	6.0 (0.7)
Carbaryl	60	8.3	2.6 (0.8)	11.1 (1.0)	5.4 (0.7)	2.0 (0.6)	11.2 (0.9)	6.2 (0.7)

[a]Total number of counts made in all of three plots per treatment before and after the treatments.
[b]Area of all fixed stations totaled for three plots by habitat.
[c]Birds counted per hectare within fixed-station areas.
[d]Includes complete fixed-station bird counts, within and outside the fixed-station area.
[e]Includes birds counted within and outside the fixed-station area.

birds showed reductions in brain cholinesterase. Carbaryl was observed to have little effect on a variety of bird species in wetland (McEwen et al. 1963, 1964) and grassland (Finley et al. 1963; McEwen et al. 1972) ecosystems.

Fixed-station Census

The total-birds variable was used to analyze counts from FS's because it offered larger numbers (Table 3), fewer zeros, and a lower coefficient of variation. Data were analyzed in two ways. First, all recorded species were tested, which resulted in a nearly significant F value ($P = 0.10$; Table 4). Also there was no significant interaction between treatment and habitat ($P = 0.48$), and the response to treatment was not different among habitats ($P = 0.49$).

The mean differences expressed as the grand mean numbers of birds per habitat prespray minus the grand mean number of birds per habitat postspray, over replication, were not significantly different between control and treated plots. Negative numbers in the following comparison indicate a postspray increase and positive numbers denote a postspray decrease.

	Douglas-fir	Aspen	Sagebrush
Control	−1.39	0.34	−1.70
Trichlorfon	0.08	0.00	0.41
Carbaryl	−0.78	−0.17	−0.27

Counts in control and carbaryl plots in all habitats (except for aspen habitat in the control FS's) indicated an average postspray increase whereas counts in trichlorfon plots either decreased or were unchanged. Although only suggestive, there appeared to be some effect from the sprays on the total population, and the effect of trichlorfon seemed to be greater than that of carbaryl.

In the second test, species that were not common to all plots or that had large or undefinable home ranges were excluded from the total birds data (leaving mostly the species listed in Table 1). Species excluded were raptors, grouse, corvids, evening grosbeaks, and pine siskins. The probability of a larger F value from the modified data was not significant ($P = 0.43$).

Table 4. *Split-plot, 3 x 3 analysis of variance of the difference between the mean of prespray and postspray counts of all species in three habitats, with three treatments and three replicates.*

Source of variation	df	Sums of squares	Mean square	F
Treatment (A)	2	5.276	2.638	3.430[a]
Error (a)	6	4.616	0.769	
Habitat (B)	2	2.786	1.393	0.864[b]
Interaction (AXB)	4	5.402	1.350	0.837[b]
Error (b)	12	19.338	1.612	
Total	26	37.418		

[a]$P = 0.10$.
[b]$P = 0.50$.

The average number of birds per hectare at the FS's (Table 3) was intended to indicate abundance over time. However, the presence of the observer affected the counts, thus diminishing their value. For example, some birds, such as Swainson's thrushes, tended to avoid observers, whereas others, such as the ruby-crowned kinglet and warbling vireo, seemed to be attracted to observers or were at least less wary. The relative smallness of some FS's precluded a sound estimate of the actual population because birds maintained a certain "safety" distance from the observer. This behavior was apparently related to habitat, since some species seemed to maintain a greater safety distance in the open sagebrush than they did in the Douglas-fir or aspen habitats.

Total birds per count in all habitats except those in the FS's in aspen consistently represented the highest mean values of the three variables (Table 3) and also had the lowest coefficient of variation. The total bird variable appears to be the best for statistical purposes; however, the technique is difficult to describe and is not precise in practice. Furthermore, the plotted line of this variable (Fig. 8) leads to the same conclusion as the other variables (i.e., that there was no appreciable population change).

The general trend of mean total birds per count remained about even before and after spraying in all plots, whereas males per count increased slightly but insignificantly (Fig. 8). Conversely, birds inside the boundaries of the FS's tended to decrease in all habitats after the treatment. The increase of singing males was probably related to the arrival of two intermediately abundant species—the western tanager and lazuli bunting.

An evaluation of changes in species composition for the 14 most abundant species after the treatments showed that none of the species disappeared from the counts, or decreased on only treated plots, in any of the three habitats (Fig. 9). Only the ruby-crowned kinglet, western tanager, lazuli bunting, dark-eyed junco, and chipping sparrow differed in appreciable numbers before and after the treatment.

Ruby-crowned kinglets were observed less frequently after treatment in all plots, but the decrease was most noticeable in trichlorfon plots. This change may have resulted from a shift in male activity from that of singing to that of feeding of young, or from insecticide effects, thus decreasing the chance of their being heard or seen. Emigration of males (which comprised a majority of the observations) is unlikely because breeding pairs of kinglets did not drop greatly in any SP (Fig. 7). When the frequencies of occurrence in all habitats are compared (Fig. 9), ruby-crowned kinglets were observed less frequently at FS's during postspray in plots treated with trichlorfon (89%) than in plots treated with carbaryl (68%) or control plots

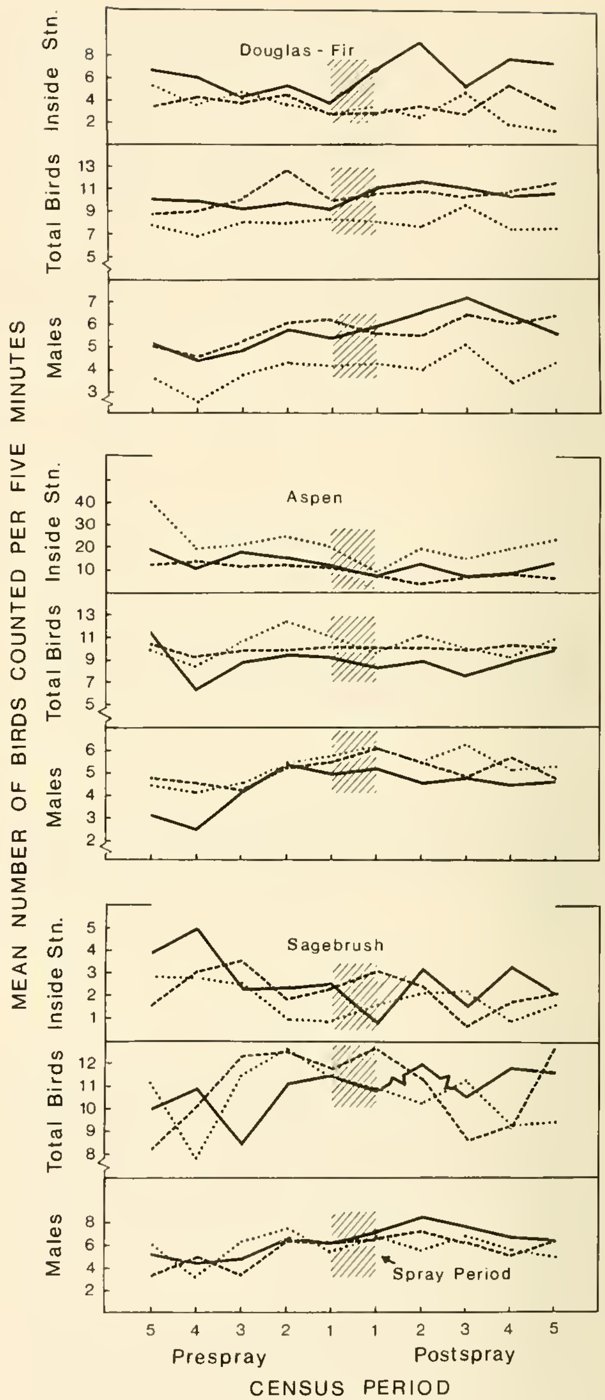

Fig. 8. Periodic means of bird counts inside the fixed stations (FS) only, the total birds, and territorial males-only observed during five counts before and after treatment from FS's positioned in Douglas-fir, quaking aspen, and sagebrush habitats. Lines are pooled data from counts at FS's in three major plots: solid lines control, dotted lines trichlorfon plots, and dashed lines from carbaryl plots.

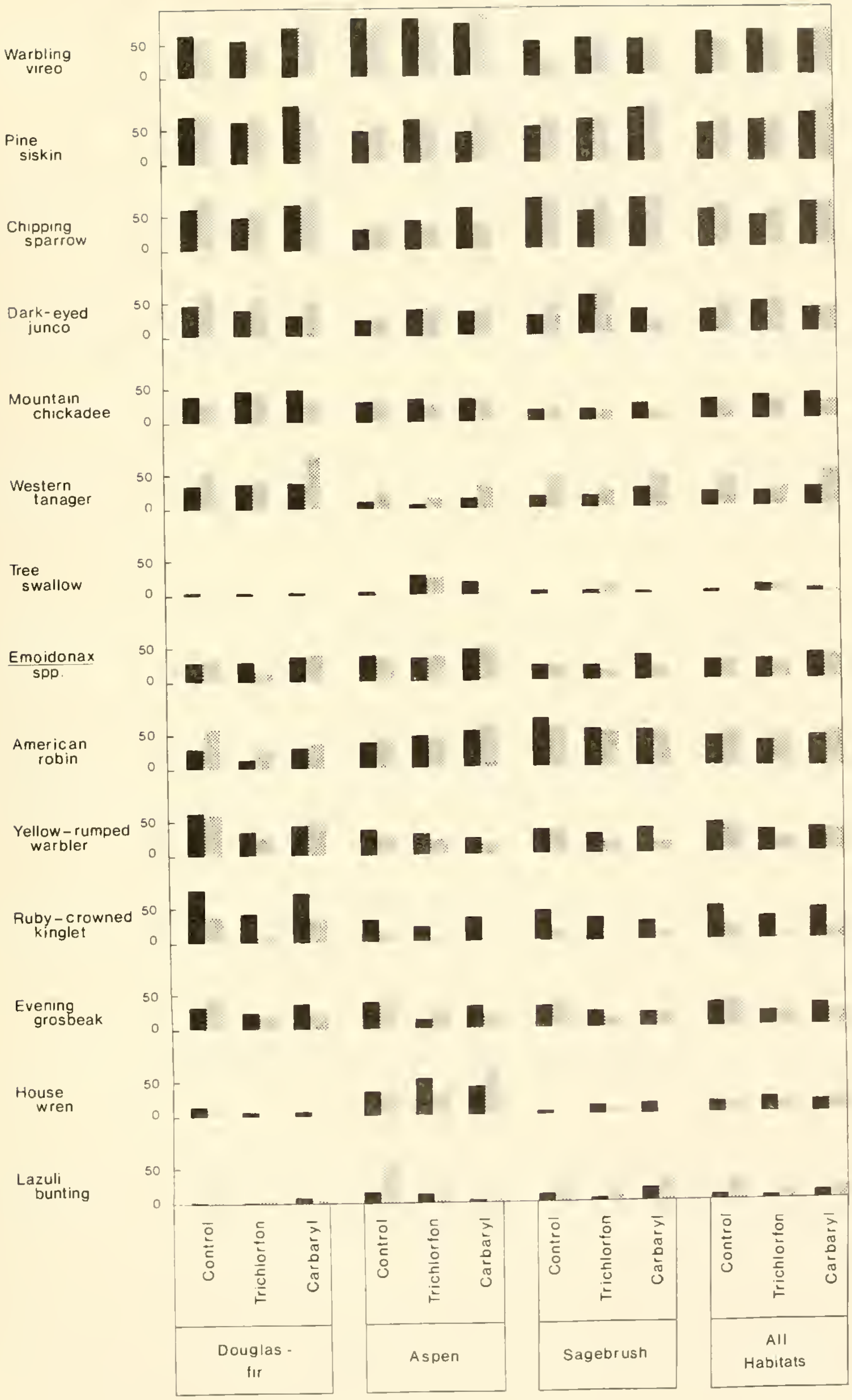

Fig. 9. Frequency of occurrence of 14 major species observed at fixed stations (FS) during five prespray (solid bars) and postspray (stippled bars) counts in three habitats.

Table 5. *Number of prespray encounters (birds sighted or heard) before treatment and percentage change after treatment for 14 abundant species recorded at fixed stations (FS's) in three habitats in treated and untreated plots.*[a]

	Treatment								
	Control			Trichlorfon			Carbaryl		
	Number of encounters			Number of encounters			Number of encounters		
Habitat	Possible no.	Actual no. prespray	Postspray change (%)	Possible no.	Actual no. prespray	Postspray change (%)	Possible no.	Actual no. prespray	Postspray change (%)
Douglas-fir	980	382	+12	1,050	322	−3	910	369	+2
Aspen	980	324	+10	896	323	−4	616	228	+8
Sagebrush	910	299	+4	840	277	−2	840	307	−9

[a]One encounter = one species tallied (seen or heard singing) during a 5-min count; number of possible encounters = number of counts per period per plot × 14 species; see Fig. 9 for the 14 species.

(66% decrease). Although the difference was not significant ($P = 0.12$), we believe that the decrease of ruby-crowned kinglets in trichlorfon-treated plots, as compared with control plots, was possibly related to the trichlorfon treatment.

Observations of western tanagers and lazuli buntings increased substantially after the spraying, probably because both species were among the last to establish breeding territories, and males sang more frequently during the postspray period. Chipping sparrow and dark-eyed junco encounters likewise increased after treatment—mostly in the Douglas-fir habitat. Both nested late in the season; male dark-eyed juncos often exhibit a surge of singing during their second nesting.

After treatment, total encounters (birds detected by sight and sound) increased about 9% in control plots, decreased (insignificantly; $P = 0.32$) about 3% in trichlorfon-treated plots, and remained essentially unchanged in carbaryl plots (Table 5).

Birds counted after the spraying inside the boundary of FS's tended to increase in Douglas-fir habitats and to decrease in aspen and sagebrush habitats (Table 3). The relation persisted for control plots but not for treated plots, wherein a consistent decrease of birds occurred for the inside station variable in all habitats. It is conceivable that birds in untreated plots used the Douglas-fir to a greater extent, perhaps for foraging, than the other habitats after the treatment date. The suppression of the western budworm by the insecticides apparently reduced some of the attractiveness of the Douglas-fir areas for birds.

Although the breeding-pair estimates and FS counts generally agreed, some results were inconsistent. Our most conflicting results involved the western tanager on all plots. Breeding pairs of this species decreased in trichlorfon SP's (Fig. 7), whereas the FS census indicated an increase on all plots (Fig. 9). One reason for this disagreement might be that factors causing changes in tanager numbers or conspicuousness varied within the sprayed MP's. Also, since tanager activity, but not numbers, increased after treatment, the breeding-pair census on SP's would not reflect such an increase in numbers as the FS count method would. We suspect that species' activity changes probably affected the FS counts more than the breeding-pair census, because the FS's were spread out in the major plots. For tanagers, where territorial density probably remained constant and the breeding activity increased after treatment, this increased postspray conspicuousness resulted in higher FS counts. Despite the inconsistencies, the general agreement of the two types of bird counts added confidence to our overall assessment of population responses to the spray treatments.

The FS count gave us a check on population changes that the breeding-pair estimate might not detect, because the FS's were scattered throughout the MP's and thus increased our chances of detecting effects on birds on the whole plot. Also, the breeding-pair estimate yielded only one value for each treatment period, whereas the FS count provided trends in species abundance.

Nesting Studies

A total of 227 nests that were active at spray time were located, of which 122 were cavity nests (Table 6). About 52% of the active nests held young at spray time; the rest had eggs. By taxonomic grouping, the relative abundance of nests was as follows: thrushes 22%; woodpeckers 17%; flycatchers and swallows 16%; house wren 14%; sparrows and juncos 13%; and warbling vireo 6%. Sixty-seven additional active nests observed before treatment were not included in the evaluation because they became inactive before treatment.

Because it was impossible for us to obtain accurate

Table 6. *Number and type of nests found on the study area that were active immediately before the spray applications.*

Species and group	Nest type[a]	Treatment: Control	Trichlorfon	Carbaryl
Goshawk	N	0	1	0
Sharp-shinned hawk	N	1	0	0
Red-tailed hawk	N	1	1	1
Golden eagle	N	0	1	0
Common flicker	C	3	4	6
Yellow-bellied sapsucker	C	6	6	3
Williamson's sapsucker	C	0	1	0
Hairy woodpecker	C	2	2	2
Downy woodpecker	C	1	1	1
Northern three-toed woodpecker	C	0	0	1
Empidonax spp. (flycatchers)	N	3	7	3
Tree swallow	C	8	13	3
Black-capped chickadee	C	1	0	0
Mountain chickadee	C	2	6	3
House wren	C	8	14	10
American robin	N	14	8	10
Swainson's thrush	N	0	0	2
Mountain bluebird	C	6	6	3
Warbling vireo	N	8	1	5
Yellow warbler	N	0	1	0
Yellow-rumped warbler	N	0	1	0
Western tanager	N	0	0	2
Pine siskin	N	0	2	0
Green-tailed towhee	N	2	0	0
Dark-eyed junco	N	5	7	3
Chipping sparrow	N	5	5	3
White-crowned sparrow	N	1	1	0
Total		77	89	61

[a]C = cavity, N = noncavity (based on nest sites used in the study area).

counts of eggs laid or young fledged in many nests (e.g., in cavity nests), we used a simplified definition of nest failure or success (Table 7). A successful nest was defined as one with advanced age nestlings in or near the nest, and with adults carrying food to the nest, or one from which the young had probably fledged after our preceding visit. Another possible method for evaluating incomplete nesting data in which nest exposure days are used was described by Mayfield (1961, 1975); however, we believe our data were sufficient for direct comparisons.

The success of nests in control plots did not differ significantly from the success in trichlorfon- and carbaryl-treated plots (Table 7) when either nests with eggs, or with young, or all nests combined were tested ($P > 0.50$; Sokal and Rohlf 1969:599). Therefore, the insecticides did not affect nest success, as we defined it. In the control plots, 74% of the nests with eggs and 97% of the nests with young at spray time were successful; these respective percentages were 83 and 100% in trichlorfon plots and 86 and 100% in carbaryl plots (Table 7). A weakness in this method of evaluating nesting success is the lack of information about the numbers of young produced per nest.

The fates of eight unsuccessful nests containing eggs in control plots were as follows: two were destroyed by predators, three were abandoned, and two fell to the ground; one nest with young was destroyed for reasons unknown. In trichlorfon plots, two nests with eggs were destroyed by predators, one each was abandoned with eggs and with young, and one was destroyed by livestock. In carbaryl plots two nests with eggs were abandoned and one was accidentally destroyed by our activities following treatment.

It appeared that birds—even those living well inside the treated plots—did not abandon the plot or their nests in abnormal numbers. Our breeding-bird and FS counts indicated that birds were still using the plots regularly after treatment with insecticides; furthermore, no impact of the treatments on nesting success could be detected. Even though budworm populations were reduced in treated plots by about 70% at 1 week

Table 7. *Percentages of successful nests among nests of known outcome, as determined at the last postspray visit to nests that were active at the time of treatment.*

Treatment, nest type, and feeding category	No. species	Nests with eggs at time of treatment: Known outcome: Nests (no.)	Fledged (%)	Outcome unknown (no.)	Nests with young at time of treatment: Known outcome: Nests (no.)	Fledged (%)	Outcome unknown (no.)
Control							
Nest type							
Cavity	9	16	73	1	19	100	1
Noncavity[a]	9	13	75	1	14	92	2
Total or weighted average	18	29	74	2	33	97	3
Feeding category							
Raptorial	2	1	100	0	1	0	1
Aerial	2	7	29	0	3	100	0
Tree canopy	2	0	0	0	3	100	0
Tree trunk	3	2	100	0	7	100	0
Understory	3	8	100	0	3	67	0
Ground	5	8	75	1	14	100	2
Air-Ground	1	3	50	1	2	100	0
Total or weighted average	18	29	74	2	33	97	3
Trichlorfon							
Nest type							
Cavity	9	19	93	4	33	100	6
Noncavity[a]	12	19	72	5	10	100	1
Total or weighted average	21	38	83	9	43	100	7
Feeding category							
Raptorial	3	0	0	0	3	100	0
Aerial	2	18	100	4	1	100	0
Tree canopy	3	0	0	0	9	100	2
Tree trunk	4	0	0	0	10	100	2
Understory	3	7	67	1	9	100	2
Ground	5	11	67	2	7	100	0
Air-Ground	1	2	0	2	4	100	1
Total or weighted average	21	38	83	9	43	100	7
Carbaryl							
Nest type							
Cavity	9	13	91	2	18	100	3
Noncavity[a]	8	12	80	2	7	100	1
Total or weighted average	17	25	86	4	25	100	4
Feeding category							
Raptorial	1	0	0	0	1	100	0
Aerial	2	4	100	0	1	100	0
Tree canopy	3	2	100	0	4	100	0
Tree trunk	4	0	0	0	7	100	1
Understory	1	7	100	2	2	100	0
Ground	5	10	75	2	9	100	2
Air-Ground	1	2	50	0	1	0	1
Total or weighted average	17	25	86	4	25	100	4

[a]Most warbling vireo nests that were active at spray time are not included because we could not see into the nests; of eight additional nests on control plots, seven were active and the status of one was unknown, one nest on trichlorfon-treated plots was active, and of three nests in carbaryl-treated plots, two were active and the status of one was unknown at the last postspray check.

Table 8. *Results of systematic searching for dead birds in three untreated and six treated major plots (no sick birds were found).*

Treatment	Prespray			Postspray		
	Search time[a]		No. dead birds found	Search time[a]		No. dead birds found
	Days	Hours		Days	Hours	
Control	10	11.0	0	8	7.5	0
Trichlorfon	10	13.0	1[b]	8	8.5	2[c]
Carbaryl	12	13.5	4[d]	7	9.0	0

[a]One search day = one person searching in one plot for 1 day, for 0.5 to 2.5 hours; one search hour = number of people searching times number of hours searched.

[b]Blue grouse adult.

[c]Partly feathered nestling dark-eyed juncos found partly ingested by garter snakes on two occasions.

[d]One adult each, yellow-rumped warbler, blue grouse, common flicker, and western tanager.

after the treatments (see following subsection on food), breeding pairs were inhabiting sprayed plots up to 2 weeks after treatment. Apparently, for the 2 weeks after treatment, there were sufficient arthropods to sustain adults and nestlings. Numbers of insects in sweep-net samples from flowering plants increased in treated and untreated plots after the treatments (Schmidt et al. 1978), suggesting that insects were available as food, at least in the lower vegetative cover.

We believe nesting success may be an important consideration in field testing of a pesticide. If adults die, lose their ability to care for young, or emigrate from the sprayed areas, increased nest failures would probably occur on treated plots. If so, other information could be used to help explain nest failures. For example, census results could confirm die-offs or emigration, carcass counts could indicate die-offs, and brain cholinesterase measurements could indicate physiological impairments in the birds.

In other studies of trichlorfon and carbaryl, as in ours, no measureable changes in nesting success have generally occurred. Pillmore et al. (1971*b*; design of study same as Pillmore 1973, Table A-4), found that 84% of 25 nests fledged or were active in two plots treated with trichlorfon (in oil at 1.1 kg active ingredient per ha) during 2 weeks postspray; all nests in a control plot held or had fledged young during the same period. Bednarek and Davidson (1967) applied carbaryl at 1.1 kg active ingredient per ha over a mixed forest in Massachusetts during the fifth breeding season of a 5-year study of nest success by six bird species using artificial nest boxes. Percentage of eggs that hatched, clutch size, and nestling mortality after treatment during peak laying was essentially the same in 34 nests during years before spraying and in 8 nests during the one season postspray. The only evidence of a possible pesticide effect was in one clutch that hatched near the time of spraying; all five young tree swallows had been dead for some time when found and contained 0.4- to 2.0-ppm concentrations of "apparent Sevin." In another study (Conner 1960), the young of three bird species were successfully reared in several nests after a New York mixed forest was sprayed with carbaryl (in oil) at 1.4 kg active ingredient per ha. Richmond et al. (1979) found no major differences in the probability of success of nest contents in control plots and plots treated with 2.2 kg active ingredient per ha carbaryl. The same was true 1 year later. Four of five nests representing three species that were active in a New Jersey area sprayed with carbaryl fledged young after treatment (Moulding 1976). No nestling mortality was observed, and the only control nests also fledged young. In a similar study involving trichlorfon and carbaryl (Doane and Schaefer 1971), 15 nests representing nine species were all successful after treatment, except for one which was lost to predation.

Casualty Searches

Searches for dead or sick birds (Table 8) indicated that mortality did not increase after the treatments. A few dead birds, but no sick birds were found, suggesting that the dead birds did not die from direct insecticide poisoning or related complications.

It is extremely difficult under most circumstances to locate small, dead birds in forest vegetation. However, since no sick birds were noted, it is unlikely that we overlooked significant mortalities.

Furthermore, these insecticides have relatively low acute and dietary toxicities to laboratory-treated birds (Heath et al. 1972; Hill et al. 1975; Tucker and Crabtree 1970; and Zinkl et al. 1977), and other workers have not observed mortality of birds under field conditions in other regions (Moulding 1976; Pillmore 1973; and Richmond et al. 1979).

Table 9. *Average percentage (range in parentheses) of animal matter, plant matter, and grit, estimated by volume, in 183 stomachs from birds of selected species collected in treated plots and untreated areas away from the study area.*

Species and category of area	Number of birds	Material		
		Animal[a]	Plant	Grit
Treated[b]				
Mountain chickadee	21	99 (90-100)	<1 (0-10)	<1 (0-5)
American robin	24	93 (0-100)	2 (0-15)	5 (0-95)
Warbling vireo	10	99 (95-100)	0 —	1 (0-5)
Western tanager	17	99 (95-100)	0 —	1 (0-5)
Evening grosbeak	17	80 (5-100)	10 (0-75)	9 (0-50)
Pine siskin	10	50 (0-90)	6 (0-60)	42 (5-90)
Dark-eyed junco	31	95 (80-100)	<1 (0-7)	5 (0-20)
Chipping sparrow	23	95 (50-100)	2 (0-40)	3 (0-50)
Totals	153	91 (0-100)	2 (0-75)	6 (0-95)
Untreated[c]				
Mountain chickadee	3	88 (85-95)	10 (0-15)	2 (0-5)
American robin	7	59 (0-100)	25 (0-90)	16 (0-95)
Warbling vireo	1	100 —	0 —	0 —
Western tanager	2	100 —	0 —	0 —
Evening grosbeak	6	63 (5-95)	34 (0-95)	3 (0-10)
Pine siskin	3	75 (60-85)	0 —	25 (15-40)
Dark-eyed junco	5	72 (25-95)	11 (0-45)	17 (0-75)
Chipping sparrow	3	65 (5-100)	25 (0-75)	10 (0-25)
Totals	30	71 (0-100)	18 (0-95)	11 (0-95)

[a]All insects and spiders except for an occasional snail.
[b]Samples collected 10-19 July.
[c]Samples collected 2-8 July.

Food

Animal matter (mostly insects) was the dominant food in the stomachs of eight bird species in the treated areas, although some plant material and grit were present (Table 9). It is likely that the dying or dead insects that were made more readily available by the insecticides' effects were consumed at a high rate.

Although differential rates of digestion of stomach contents can bias the interpretation of food habits toward insects that digest more slowly than others (Coleman 1974), we found that numbers of individual soft-bodied insects in the stomachs (lepidopteran larvae) still exceeded those insects with more resistant parts, such as adult Coleoptera and Hymenoptera. Larvae of Lepidoptera contributed 68 to 95% of the individual identifiable insects found in all bird species.

Larvae of the black-headed budworm, cone moth, and perhaps loopers (Geometridae) were possibly sometimes confused with the larval western budworm when the stomach contents were partly decomposed. However, most of the western budworm larvae in the stomachs in our samples were large and well developed, and we were able to use the key characteristics of the western budworm in its late instar stages (Patrick J. Shea, personal communication) for identification.

Four species, the American robin, evening grosbeak, warbling vireo, and western tanager, had the highest occurrence of western budworms per bird in their stomachs (Table 10). All the species listed in Table 10 except the American robin, dark-eyed junco, and to some extent the pine siskin and chipping sparrow, are canopy-feeding species. The robin is an opportunistic ground-feeding omnivore (Martin et al. 1951), and probably ate fallen budworms after the spraying. Robins ($n = 5$) had more budworms in their stomach contents on the day of spray (40 per bird) than any of the other seven species (one to seven per bird; $n = 49$). Budworms that had fallen to the ground and others affected by the spray that were falling from the trees on their silk threads were readily visible within a few hours after the treatments.

Western budworms were found in stomachs of the eight species in 66% of the individuals collected in trichlorfon-treated MP 4, where we collected one-third of the samples of the eight species (Table 10). Budworms were found in only 30% of the birds of the same eight species collected in the other five treated plots. Western budworms were found in 17% of the birds collected in untreated areas, but budworm populations were not

Table 10. *Occurrence of western budworm larvae in stomachs of eight bird species collected in treated and untreated areas.*

Species	Number of birds	Percentage occurrence[a]	Average number of western budworms per bird: All birds	Average number of western budworms per bird: Birds with larvae
Mountain chickadee	24[b]	21	0.4	2.0
American robin	31[b]	48	13.6	28.2
Warbling vireo	11[b]	18	1.7	8.5
Western tanager	19[b]	53	2.9	5.6
Evening grosbeak				
Treated areas	17	65	12.8	19.7
Untreated areas	6	67	14.0	21.0
Pine siskin				
Treated areas	10	50	1.5	3.0
Untreated areas	3	33	0.7	2.0
Dark-eyed junco	36[b]	42	1.4	3.5
Chipping sparrow	26[b]	23	0.5	2.3
Totals or means	183	40	4.9	12.1

[a]Percentage of all bird stomachs containing one or more western budworms.

[b]Additional numbers of each species—three chickadees, seven robins, one vireo, two tanagers, five juncos and three sparrows—that were collected in untreated areas adjacent to the study plots did not contain western budworms; all other birds listed except as noted were collected in sprayed plots.

determined in these untreated areas. The high incidence of western budworms in the stomachs from MP 4 could be a function of availability due to the insecticide kill, density of the budworm population, or both—although an apparent higher population of budworms occurred in plot 4 (Table 11). Budworm populations also were high in MP 8 (Table 11); however, we collected few birds there.

Table 11. *Numbers of western budworms counted per 100 buds in the nine major plots, before and after the treatments.*[a]

Plot and treatment	Prespray	Days after treatment: 7	Days after treatment: 14
Control			
1	27.4	27.7	22.8
3	17.4	18.0	18.4
9	13.3	12.4	8.4
Trichlorfon			
4	25.5	8.0	5.1
5	19.3	6.2	4.4
7	11.6	3.8	1.6
Carbaryl			
2	18.5	6.0	4.0
6	13.7	2.5	1.9
8	25.5	6.5	3.1

[a]Reprinted with permission of Flavell et al. (1978).

Western budworm larvae represented nearly 50% of the total insects in stomachs of the evening grosbeak, American robin, pine siskin, and western tanager, in decreasing order (Table 12). Assessment of food intake in larger birds, such as the American robin and evening grosbeak, was more complete because most of the food they had eaten could be readily identified.

Because prespray birds were collected in untreated areas adjacent to the control plots, where population estimates of western budworms are lacking, prespray versus postspray comparisons are not clear-cut; however, we believe that budworm availability was probably lower in the areas of prespray collection.

We developed an avian feeding potential for the species we examined (Table 9) by multiplying the number of birds per hectare (from Table 1) by the average number of budworms per bird (a procedure modified from Mitchell 1952). The American robin showed the highest feeding potential (12.5; Table 13). The densities of evening grosbeaks and pine siskins could not be estimated with the same accuracy as those of the other six species from our own counts. Although not directly quantifiable from our data, grosbeaks were probably about as abundant as the western tanagers, giving them a feeding potential of 5.9. The warbling vireo was the most abundant species examined; however, it had a low western budworm feeding potential, 1.9. Feeding potentials of all species except the robin and evening grosbeak were below 2.0.

Table 12. *Percentages of total insects composed of western budworms, and of other insects or spiders in birds taken from plots treated with carbaryl or trichlorfon.*

Species	Number of stomachs examined	Total identifiable insects (no.)	Organism: Western budworm	Organism: Total Lepidoptera[a]	Organism: Other arthropods[b]	Organism: Unidentifiable arthropods
Mountain chickadee	21	97	10	68	22	10
American robin	24	778	54	95	4	1
Warbling vireo	10	73	23	79	14	7
Western tanager	17	149	40	70	17	13
Evening grosbeak	17	360	60	98	1	1
Pine siskin	10	31	48	97	0	3
Dark-eyed junco	31	201	27	70	16	14
Chipping sparrow	23	138	11	71	19	10

[a]Essentially all larval forms; includes western budworms.
[b]Nearly all were adult Coleoptera or Hymenoptera, or Araneida.

Table 13. *Feeding potential of selected bird species on western budworm larvae during the postspray period in treated plots.*

Species	No. of pairs per 100 ha[a]	Number of stomachs sampled	Number of larva budworms per bird[b]	Feeding potential[c]
American robin	34.3-57.6	31	13.6	12.5
Evening grosbeak[d]	17.2-28.8	17	12.8	5.9
Warbling vireo	37.6-75.4	11	1.7	1.9
Western tanager	17.2-28.8	19	2.9	1.3
Dark-eyed junco	30.2-50.8	36	1.4	1.1
Chipping sparrow	40.3-60.3	26	0.5	0.5
Mountain chickadee	39.8-43.9	24	0.4	0.3
Pine siskin[e]	30.0	10	1.5	0.9

[a]Range of breeding-pair density in the nine 8.1-ha plots; the high value = the total number of pairs estimated (border pairs called a full pair) for the 8.1-ha plot and the low value = the density for 13.6 ha to account for additional peripheral area occupied by pairs with their territories dissected by the plot border.
[b]Mean number of western budworm larvae per stomach for all birds sampled.
[c]Average number of pairs per hectare × 2 × average number of western budworms per bird = feeding potential.
[d]An estimate based on relative abundance of other species determined in this study.
[e]Estimates from a large area adjacent to our study plots (Skaar 1969).

Our food investigation revealed some changes in predation on the western budworm by birds as the budworm population decreased in treated plots; however, our samples were too small to make statistical comparisons. The numbers of western budworm larvae in the pooled stomachs of tree-canopy feeding species in Table 9 (see Table A-1 for feeding categories), expressed as an average precent of total insects per bird over several plots, was 30% on spray day in MP's 2, 4, 6, and 8 (n = 31 birds); 52% on 2 days postspray in MP's 5 and 6 (n = 16); and 61% on 5 days postspray in MP's 2 and 4 (n = 19). Percentages for ground feeders in the same MP's and at the same times were 60 (n = 23); 24 (n = 16); and 77 (n = 16). It appears that ground-feeding species, led by the robin, keyed on the budworm beginning with spray day, whereas the tree-canopy feeders used the budworm more heavily 5 days postspray. Both foraging groups increased the consumption of budworm at 5 days postspray, at a time when larvae populations were becoming reduced by 70% in the coniferous foliage (Table 11; 7 days postspray).

Occurrence of Spray on Birds

All birds collected on days 2 and 3 postspray showed evidence of the dye (Table 14). The dye was found most frequently on the feet of the 10 species examined (66% of 202 samples); in only 8% was it found only on the

plumage. Dye marks were found on the plumage or feet 5 days after treatment, but at a lower frequency than on birds collected on the day of spraying. Spray on the bodies occurred in decreasing frequencies among birds found in the treetops (80%), within the canopy (71%), and near the ground (70%). A test of the equality of two percentages (Sokal and Rohlf 1969:607), however, showed that the probability of not encountering the dye was not significantly different among groups ($P = 0.08$). The forest canopy apparently provided only limited protection to birds by intercepting the spray and lowering the amount that reached the understory vegetation.

The Lincoln's sparrow, found exclusively in open willows along streams, was exposed to the spray at a frequency similar (82%) to that found on the species dwelling in treetops (80%) (Table 14). This seems logical, since the willows were in open areas, and thus were not protected by an overstory of trees. All of the treetop dwelling western tanagers and warbling vireos that we collected had dye on them, suggesting that the birds living in the treetops came in greater contact with the spray than did other birds, either directly or from contaminated foliage.

Relation of Insecticides to Cholinesterase in Birds

Cholinesterase (ChE) determinations were made on brain tissue of 13 bird species collected in treated areas. Ninety were collected in carbaryl plots and 103 in trichlorfon plots through 5 days postspray. Ludke et al. (1975) considered that at least a 20% reduction in normal brain ChE activity was necessary to indicate exposure to a ChE inhibiting compound. ChE activities that were depressed by two standard deviations or 20% below prespray levels were found in nine birds of five species (Zinkl et al. 1977): one dark-eyed junco, two evening grosbeaks, three mountain chickadees, two western tanagers, and one Lincoln's sparrow. Six were from trichlorfon plots and three were from carbaryl plots. The greatest depression ($\geqslant$ 20% below prespray levels of ChE activities) was found in two evening grosbeaks and two western tanagers; two tanagers and one grosbeak were from trichlorfon plots, and one grosbeak came from a carbaryl plot. These data, along with the results of our bird counts, and occurrence of dye, suggest that effects of the sprays on

Table 14. *Occurrence of automate-red dye after aerial applications of insecticides containing the dye, on the plumage or feet of birds that generally live in different parts of the forest.*

	Days after treatment											
	0		1		2		3		5		Overall	
Species and habitat	Total no.	With dye (%)	Total no.	With dye (%)	Total no.	With dye (%)	Total no.	With dye (%)	Total no.	With dye (%)	Total no.	With dye (%)
Treetop												
Yellow-rumped warbler	0	—	3	66	2	100	1	100	0	—	6	83
Western tanager	11	100	3	100	4	100	0	—	1	100	19	100
Warbling vireo	9	100	0	—	1	100	0	—	1	100	11	100
Pine siskin	11	82	1	100	0	—	0	—	6	33	18	67
Evening grosbeak	6	66	5	60	1	100	0	—	8	50	20	60
Total	37	89	12	75	8	100	1	100	16	50	74	80
Below treetop												
Mountain chickadee	10	80	6	66	0	—	0	—	5	20	21	62
Chipping sparrow	13	92	2	100	4	100	0	—	8	38	27	78
Total	23	87	8	75	4	100	0	—	13	31	48	71
Near ground, open area												
American robin	11	36	10	90	1	100	1	100	8	62	31	64
Dark-eyed junco	19	84	4	100	4	100	2	100	9	22	38	74
Total	30	67	14	93	5	100	3	100	17	41	69	70
Near ground, bushes												
Lincoln's sparrow	4	100	1	100	0	—	2	100	4	50	11	82
Grand total	94	82	35	83	17	100	6	100	50	42	202	74

populations (although statistically insignificant) were small, but that birds living in the treetops probably received the greatest exposure to the chemicals.

Recommendations for Future Studies

Improvements in study design that would increase the probability of detecting effects of organophosphorus or carbamate insecticides on forest birds in similar studies are as follows: (1) spray plots of no less than 750 ha, (2) monitor the effects on canopy-dwelling species more intensively than the effects on other species, and (3) estimate the abundance of insects that insectivorous birds eat before and after treatment. A minimum of three replicates of treated and untreated plots (as used in the present study) is also needed for statistical purposes.

A minimum plot size of 750 ha is necessary for these reasons: (1) treated areas that are well away from bird-count sites are needed to collect birds for studies of brain cholinesterase activities, (2) plots need to be large enough to adequately encompass the singing and foraging territories of birds, and (3) a large buffer of sprayed area is needed between bird-count sites and the plot edge so that birds cannot easily move between sprayed and unsprayed areas.

Since canopy-dwelling bird species seem to be most exposed to aerially applied forest insecticides, more effort should be extended to those species. This could be done by (1) collecting adequate numbers (8 to 10) per collecting time of each species for cholinesterase study during prespray and at specific intervals postspray as an indicator of exposure to insecticides, and (2) making an intensive effort to locate nests of canopy-dwelling species. Locating nests in tree canopies is difficult, but some information about canopy nests could be collected.

Candidate insecticides that have reached the pilot-testing stage by passing laboratory and small-scale field tests of efficacy and hazard are seldom likely to cause obvious bird mortalities. However, a subtle but potentially severe effect on insectivorous birds can result from a persistent reduction of insect abundance after treatment. This may occur a few days after the immediate kill of insects and last for an unknown length of time. Changes in consumption of insects by birds and in insect abundance after treatment should be measured by (1) identifying and quantifying insects in stomachs of birds collected concurrently before and after the treatment in sprayed and unsprayed areas (these birds serve also as samples for cholinesterase studies) and (2) using entomological techniques to quantify populations of insects that are important bird foods.

Incorporation of the above methodologies, along with searching for dead and affected birds, behavior studies, monitoring nests of the general population, and conducting population estimates are the best approaches for detecting short-term effects of aerially applied organophosphorus and carbamate insecticides on forest birds. Richmond et al. (1979) recommended the following research methods that should receive the highest priority (in order of decreasing importance): (1) studies of brain cholinesterase activity, (2) nesting studies, (3) behavior studies, and (4) population studies. The main value here is that any one of the four listed methodologies, all of which measure specific aspects about the same population, can be helpful in interpreting the results from any of the other three approaches.

Conclusion

We detected no significant effects of trichlorfon or carbaryl sprays on the numbers of breeding pairs, bird abundance, nest success, mortality rates, or the activities of brain cholinesterase in the breeding population. However, two types of live-bird censuses showed that statistically nonsignificant postspray declines of bird numbers occurred more on trichlorfon plots than on carbaryl plots, and that the species involved lived in the treetops.

Three factors indicated that at least some birds were exposed to the insecticide sprays. First, some species ate large numbers of western budworms after the spraying (presumably because they became more readily available); second, a tracer dye in the sprays was found on about three-fourths of the birds examined, indicating direct contact with the sprays; and third, a few individuals (9 of 193) sampled had brain cholinesterase inhibitions great enough to indicate physiological exposure to the insecticides. Trichlorfon showed more potential effects on birds than carbaryl, but neither compound, at the rate applied and under the test conditions, posed a threat to birds that could be measured by the techniques that we used.

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Appendix

Table A-1. *List of common and scientific names of birds, mammals, insects, and plants used in the text and tables.*[a]

Group and common name[b]	Scientific name
Birds	
Goshawk—R	*Accipiter gentilis*
Sharp-shinned hawk—R	*A. striatus*
Red-tailed hawk—R	*Buteo jamaicensis*
Golden eagle—R	*Aquila chrysaetos*
Blue grouse—G	*Dendragapus obscurus*
Ruffed grouse—G	*Bonasa umbellus*
Mourning dove	*Zenaida macroura*
Common flicker—G	*Colaptes auratus*
Yellow-bellied sapsucker—TT	*Sphyrapicus varius*
Williamson's sapsucker—TT	*S. thyroideus*
Hairy woodpecker—TT	*Picoides villosus*
Downy woodpecker—TT	*P. pubescens*
Northern three-toed woodpecker—TT	*P. tridactylus*
Empidonax (flycatchers)—A	*Empidonax* spp.
Tree swallow—A	*Iridoprocne bicolor*
Black-capped chickadee—TC	*Parus atricapillus*
Mountain chickadee—TC	*P. gambeli*
House wren—U	*Troglodytes aedon*
American robin—G	*Turdus migratorius*
Hermit thrush	*Catharus guttatus*
Swainson's thrush—G	*C. ustulatus*
Mountain bluebird—AG	*Sialia currucoides*
Ruby-crowned kinglet—TC	*Regulus calendula*
Warbling vireo—TC	*Vireo gilvus*
Yellow warbler	*Dendroica petechia*
Yellow-rumped warbler—TC	*D. coronata*
MacGillivray's warbler—U	*Oporornis tolmiei*
Western tanager—TC	*Piranga ludoviciana*
Evening grosbeak	*Hesperiphona vespertina*
Lazuli bunting—U	*Passerina amoena*
Cassin's finch	*Carpodacus cassinii*
Pine siskin—TC	*Carduelis pinus*
Green-tailed towhee—U	*Pipilo chlorurus*
Dark-eyed junco (Oregon race)—G	*Junco hyemalis*
Chipping sparrow—G	*Spizella passerina*
White-crowned sparrow—G	*Zonotrichia leucophrys*
Lincoln's sparrow	*Melospiza lincolnii*
Mammals	
Elk	*Cervus canadensis*
Mule deer	*Odocoileus hemionus*
Moose	*Alces alces*
Insects	
Western budworm	*Choristoneura occidentalis*
Spruce budworm (Eastern)	*C. fumiferana*
Cone moth	*Dioryctria reniculella*
Black-headed budworm	*Acleris variana*
Gypsy moth	*Porthetria dispar*
Plants	
Douglas-fir	*Pseudotsuga menziesii*
Lodgepole pine	*Pinus contorta*
Limber pine	*P. flexilis*
Ponderosa pine	*P. ponderosa*
True firs	*Abies* spp.
Spruce	*Picea* spp.
Willow	*Salix* spp.
Birch	*Betula* spp.
Quaking aspen	*Populus tremuloides*
Sagebrush	*Artemisia tridentata*
Idaho fescue	*Festuca idahoensis*

[a]Authorities for the names follow: birds—Robbins et al. (1966), American Ornithologists' Union (1957, 1973, 1976); mammals—Burt and Grossenheider (1952); insects—McNight (1968) and Borrer and DeLong (1970); and plants—Jacques (1959), Brockman (1968), and Booth (1972).

[b]Symbols following common names indicate feeding categories used in text tables 2 and 7 (symbols are not shown for species not represented in these tables); A—aerial; AG—aerial and ground; G—ground; R—raptorial; TC—tree canopy; TT—tree trunk; and U—understory.

Table A-2. *Location, direction of exposure, approximate size, and treatment assignment of the nine major study plots.*

Major plot	Elevation (m)	Location[a] T R	S	Direction of tributary drainage	Major tributary	Approximate area (ha)	Treatment	Date of treatment in July
1	1890-2380	3S 2W	29,31,32,33	E	North Meadow Creek	350	None	—
2	1890-2240	4S 2W	28,29,33	E	South Meadow Creek	440	Carbaryl	10
3	1950-2250	9S 3W	29,32	NE	Clear Creek	350	None	—
4	2270-2290	8S 3W	26,27,34,35	S	North Fork Warm Springs Creek	490	Trichlorfon	14
5	1890-2190	8S 2W 9S 2W	35,36 1,2	E	Cherry Gulch[b]	500	Trichlorfon	16
6	1890-2380	9S 3W 9S 2W	24,25 17,18,19,20	W	Middle Fork Warm Springs Creek	500	Carbaryl	11
7	2010-2380	9S 3W	21,25 26,35,36	NW	South Fork Warm Springs Creek	550	Trichlorfon	17
8	1900-2380	9S 1W	7,8,17,18,19,20	NE	Ruby Creek	460	Carbaryl	12
9	1860-2250	9S 1W 10S 1W	34,35 2,3	NE	Nickerson Creek	350	None	—

[a]The distance between the two plots farthest apart (1 and 9) was 50 km.
[b]All drainages except Cherry Gulch had permanent running water.

Table A-3. *Schedule of bird counts (C) and insecticide treatments (T) for nine major study plots.*[a] *Treatments were made on 10-17 July (except 13 and 15 July, when rain intensified). No bird counts were made on 30 June or 7-10 July.*

Date		Plots prespray 1	2	3	4	5	6	7	8	9
June	20		C			C				C
	21	C					C	C		
	22			C	C				C	
	23		C			C				C
	24	C								
	25						C	C		
	26			C	C				C	
	27		C			C				C
	28	C	C				C	C		
	29			C	C				C	
	30									
July	1		C			C				C
	2	C					C	C		
	3			C	C				C	
	4		C			C				C
	5	C					C	C		
	6			C	C				C	
	10		T							
	11		C			C	T			C

Date		Plots postspray 1	2	3	4	5	6	7	8	9
July	12	C					C	C	T	
	13		C	C					C	
	14				T		C			C
	15				C				C	
	16	C		C		T				
	17		C			C		T		C
	18				C		C	C		
	19	C				C			C	
	20		C	C				C		
	21				C		C			C
	22	C				C			C	
	23		C	C				C		
	24						C			C
	25				C	C			C	
	26	C								
	27		C	C				C		
	28				C		C			
	29					C			C	
	30			C				C		

[a]Plots 1, 2, and 4 were assigned to one observer; plots 3, 5, and 6 to a second; and 7, 8, and 9 to a third. Bird counts included breeding-pair and fixed-station (FS) counts.

Table A-4. *Number and average areas (ha) of fixed-station (FS) plots located in each of the three major habitats in each major plot (MP).*

	Habitat					
	Douglas-fir		Aspen		Sagebrush	
Major plot[a]	Number of stations	Average area (ha)	Number of stations	Average area (ha)	Number of stations	Average area (ha)
1	5	0.38	5	0.20	5	0.61
2	5	0.42	3	0.38	4	0.63
3	4	0.37	4	0.24	4	0.50
4	5	0.42	3	0.26	5	0.74
5	5	0.42	5	0.09	2	0.33
6	4	0.42	5	0.37	4	0.70
7	5	0.42	5	0.48	4	0.65
8	4	0.42	1	0.39	4	0.73
9	5	0.42	5	0.42	4	0.42
Total or means	42	0.41	36	0.30	36	0.61

[a]Treatments: Control—1,3,9; Trichlorfon—4,5,7; and Carbaryl—2,6,8.

Table A-5. *Summary of nine field studies following applications of carbaryl (Sevin-4-oil; studies 1 to 9) and three following application of trichlorfon (Dylox; studies 10 to 12).*[a]

Study no.	Rate per hectare and formulation	Area (ha) Treatment	Bird study[b] plot	Habitat	Number of plots Treated	Untreated	Nest studies	Number of bird counts Prespray	Postspray[c]	Source
1	1.4 kg in 9.3L fuel oil	30,375	ND	Varied	4	0	No	0	0	Connor (1960)
2	0.6 kg in 18.7 L H_2O	ND	ND	Rangeland	ND	ND	No	ND	ND	Finley et al. (1963:58)
3	1.1 kg in 9.3 L H_2O	810	Transects	Grassland and potholes	1	1	ND	ND	ND	McEwen et al. (1963:57)
4	1.1 kg	ND	4.0	Pine forest	1	0	Yes	ND	ND	Bednarek and Davidson (1967)
5	0.4 kg	65	Transects	Shortgrass plains	4	ND	No	—	28	McEwen et al. (1972)
6	1.1 kg in 2.3 L H_2O	20	Central 15.0	Oak woodland	1	1	Yes	16	16	Doane and Schaeffer (1971)
7	1.1 kg in 9.3 L H_2O + 113.4 g adhesive sticker	2,025	3.0	Deciduous forest	2	2	Yes	3-4	11-12	Moulding (1976)
8	2.2 kg in diesel oil	130	Central 81	Coniferous forest	2	3	Yes	4	4	Richmond et al. (1979)
9	1.1 kg in 4.7 L diesel oil	350-550	8.1 and 9-15x0.6	Coniferous forest	3	3	Yes	5	5	Present study
10	1.1 kg in 2.3 L summer oil	20	Central 15.0	Oak woodland	1	1	Yes	16	16	Doane and Schaeffer (1971)
11	1.1 kg in oil	65	Central 16.2	Coniferous forest	1	1	Yes	4	4	Pillmore (1973)
12	1.1 kg in 9.4 L Panasol AN3	350-550	8.1 and 9-15x6.0	Coniferous forest	3	3	Yes	5	5	Present study

[a]States in which studies were conducted were as follows: 1—New York; 2, 9 and 12—Montana; 3—North Dakota; 4—Massachusetts; 5—New Mexico; 6 and 10—Connecticut; 7—New Jersey; 8—Oregon; and 11—Colorado. ND = no data collected or reported; no mortalities were reported, except in study no. 2 where possible small mammal mortality occurred and 1 ppm residues were found in one bird; in study no. 3, residues of some bird samples had <6 ppm carbaryl residues and most had trace amounts; residues 1 year postspray ranged from 0.1 to 0.8 ppm; study plots in no. 7 were located within an area sprayed operationally for gypsy moth; possible effects occurred on nestling tree swallows that were found dead in study no. 4 with carbaryl residues 16 days after spraying; a reduction in bird populations was noted only in study no. 7; none in 5-6 or 8-12; no data for 1-4; carbaryl used in studies 5, 6, 8, and 9 was Sevin-4-oil formulation; the carbaryl formulation used in studies 1-4 and 7 was not reported; studies of carbaryl were 1-9; and those of trichlorfon were 10-12.

[b]In study no. 3, two 6.4-km transects in upland areas and two transects in pothole areas were used.

[c]In study no. 5, 28 total bird counts were made but the numbers of counts made before or after the treatment were not reported.

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